ORGANIC LIGHT-EMITTING DIODE DISPLAYS WITH SEMICONDUCTING-OXIDE AND SILICON THIN-FILM TRANSISTORS

This application claims the benefit of provisional patent application No. 61/869,937, filed Aug. 26, 2013, which is hereby incorporated by reference herein in its entirety.

BACKGROUND

This relates generally to electronic devices and, more particularly, to electronic devices with displays that have thin-film transistors.

Electronic devices often include displays. For example, cellular telephones and portable computers include displays for presenting information to users.

Displays such as liquid crystal displays are formed from multiple layers. A liquid crystal display may, for example, have upper and lower polarizer layers, a color filter layer that contains an array of color filter elements, a thin-film transistor layer that includes thin-film transistors and display pixel electrodes, and a layer of liquid crystal material interposed between the color filter layer and the thin-film transistor layer. Each display pixel typically includes a thin-film transistor for controlling application of a signal to display pixel electrode structures in the display pixel.

Displays such as organic light-emitting diode displays have an array of display pixels based on light-emitting diodes. In this type of display, each display pixel includes a light-emitting diode and thin-film transistors for controlling application of a signal to the light-emitting diode.

Thin-film display driver circuitry is often included in displays. For example, gate driver circuitry and demultiplexer circuitry on a display may be formed from thin-film transistors.

If care is not taken, thin-film transistor circuitry in the display pixels and display driver circuitry of a display may exhibit non-uniformity, excessive leakage currents, insufficient drive strengths, poor area efficiency, hysteresis, and other issues. It would therefore be desirable to be able to provide improved electronic device displays.

SUMMARY

An electronic device may be provided with a display. The display may have an array of display pixels on a substrate. The display pixels may be organic light-emitting diode display pixels or display pixels in a liquid crystal display.

In an organic light-emitting diode display, hybrid thin-film transistor structures may be formed that include semiconducting oxide thin-film transistors, silicon thin-film transistors, and capacitor structures. The capacitor structures may overlap the semiconducting oxide thin-film transistors. Capacitor structures may also be formed from multiple overlapping electrode layers formed from source-drain metal layers, a polysilicon layer, and a gate metal layer may be used.

Organic light-emitting diode display pixels may have combinations of oxide and silicon transistors. Transistors such as drive transistors that are coupled to light-emitting diodes may be formed from oxide transistor structures and switching transistors may be formed from silicon transistor structures.

In a liquid crystal display, display driver circuitry may include silicon thin-film transistor circuitry and display pixels may be based on oxide thin-film transistors. A single layer or two different layers of gate metal may be used in forming silicon transistor gates and oxide transistor gates. A silicon transistor may have a gate that overlaps a floating gate structure. Oxide transistors may be incorporated into display driver circuitry.

Display driver circuitry may be configured to expose silicon transistor circuitry to lower voltage swings than oxide transistor circuitry in an array of display pixels.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram of an illustrative display such as an organic light-emitting diode display having an array of organic light-emitting diode display pixels or a liquid crystal display having an array of display pixels in accordance with an embodiment.

FIG. **2** is a diagram of an illustrative organic light-emitting diode display pixel of the type that may be used in an organic light-emitting diode with semiconducting oxide thin-film transistors and silicon thin-film transistors in accordance with an embodiment.

FIG. **3** is a cross-sectional side view of illustrative thin-film transistor structures in accordance with an embodiment.

FIG. **4** is a side view of additional illustrative thin-film transistor structures in accordance with an embodiment.

FIG. **5** is a diagram of an illustrative organic light-emitting diode display pixel of the type that may include oxide and silicon thin-film transistors in accordance with an embodiment.

FIGS. **6**, **7**, and **8** are cross-sectional side views of illustrative thin-film transistor circuitry in a liquid crystal display in accordance with an embodiment.

FIG. **9** is a diagram of an illustrative complementary metal-oxide-semiconductor transistor inverter of the type that may be formed from a hybrid silicon-oxide transistor structure in accordance with an embodiment.

FIG. **10** is a cross-sectional side view of an illustrative thin-film transistor structure of the type that may be used to form a hybrid complementary metal-oxide-semiconductor transistor inverter in accordance with an embodiment.

FIG. **11** is a circuit diagram of gate driver circuitry in thin-film display driver circuitry in accordance with an embodiment.

FIG. **12** is a diagram of a level shifter of the type that may be used in the gate driver circuitry of FIG. **11** within display driver circuitry on a display in accordance with an embodiment.

FIG. **13** is a circuit diagram of an illustrative circuit that may be used to prevent transistors within display driver circuitry on a display from experiencing excessive voltages in accordance with an embodiment.

FIG. **14** is a cross-sectional side view of illustrative thin-film transistor circuitry in a liquid crystal display in accordance with an embodiment.

DETAILED DESCRIPTION

A display in an electronic device may be provided with driver circuitry for displaying images on an array of display pixels. An illustrative display is shown in FIG. **1**. As shown in FIG. **1**, display **14** may have one or more layers such as substrate **24**. Layers such as substrate **24** may be formed from planar rectangular layers of material such as planar glass layers. Display **14** may have an array of display pixels **22** for displaying images for a user. The array of display pixels **22** may be formed from rows and columns of display pixel structures on substrate **24**. There may be any suitable number of rows and columns in the array of display pixels **22** (e.g., ten or more, one hundred or more, or one thousand or more).